LOWER WILLAMETTE RIVER
WINTER 2004
MULTIBEAM BATHYMETRIC SURVEY REPORT

September 2004

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This document is currently under review by US EPA and its federal, state and tribal partners, and is subject to change in whole or in part.

Prepared for:
Lower Willamette Group

Prepared by:
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David Evans Associates, Inc.
2828 SW Corbett Ave.
Portland, OR 97201

September 9, 2004

Chip Humphrey
Eric Blischke
US Environmental Protection Agency, Region 10
811 SW 6th Avenue, 3rd Floor
Portland, OR 97204

Re: Lower Willamette River, Portland Harbor Superfund Site
USEPA Docket No: CERCLA-10-2001-0240
Portland Harbor RI/FS – Winter 2004 Precision Bathymetric Survey

Dear Mssrs. Humphrey and Blischke:

This letter transmits the results of the multibeam bathymetric survey that took place in the Lower Willamette River during the winter of 2004. This fourth bank-to-bank survey was conducted immediately following a relatively high flow event (over 120,000 cubic feet/second) that occurred on the Lower Willamette River on January 31-February 1, 2004. The data from this survey were compared to the riverbed elevation data collected in May 2003 (third survey) as well as the data collected during the first bathymetric survey of the site in December 2001/January 2002 (hereafter referred to as the January 2002 survey).

The winter 2004 bathymetric survey was conducted by David Evans and Associates, Inc (DEA) from February 6 through March 6, 2004. As in the previous surveys, the area surveyed extended from River Mile 0 (the confluence with the Columbia River) to River Mile 15.6 (the upper end or Ross Island). The methods used to collect and post-process the riverbed elevation data are described in a survey report prepared by DEA and included here as Attachment A. As with the previous data sets, the survey data were processed using a grid size of 1 meter by 1 meter to generate a digital terrain model (DTM).

The results of the winter 2004 survey are provided here in both contour (Figures 1a-k) and hill shade (Figures 2a-k) formats. Water depths are referenced to the North American Vertical Datum of 1988 (NAVD88). In addition, two sets of bathymetric survey difference maps were produced. Figures 3a-k show areas of riverbed elevation change (shallowing, deepening, and no change) over the 25-month period from January 2002 to February 2004, and Figures 4a-k show areas of riverbed elevation change over the 8-month period from May 2003 to February 2004.

This report also includes a digital copy of the February 2004 data. The enclosed CD contains edited x, y, and z data (February 2004 bathymetry and bathymetric differences) and AutoCAD files of the contour maps. If you have any questions, please give me a call at (360) 705-3534.

Sincerely,

Gene C. Revelas
RI Sampling Coordinator

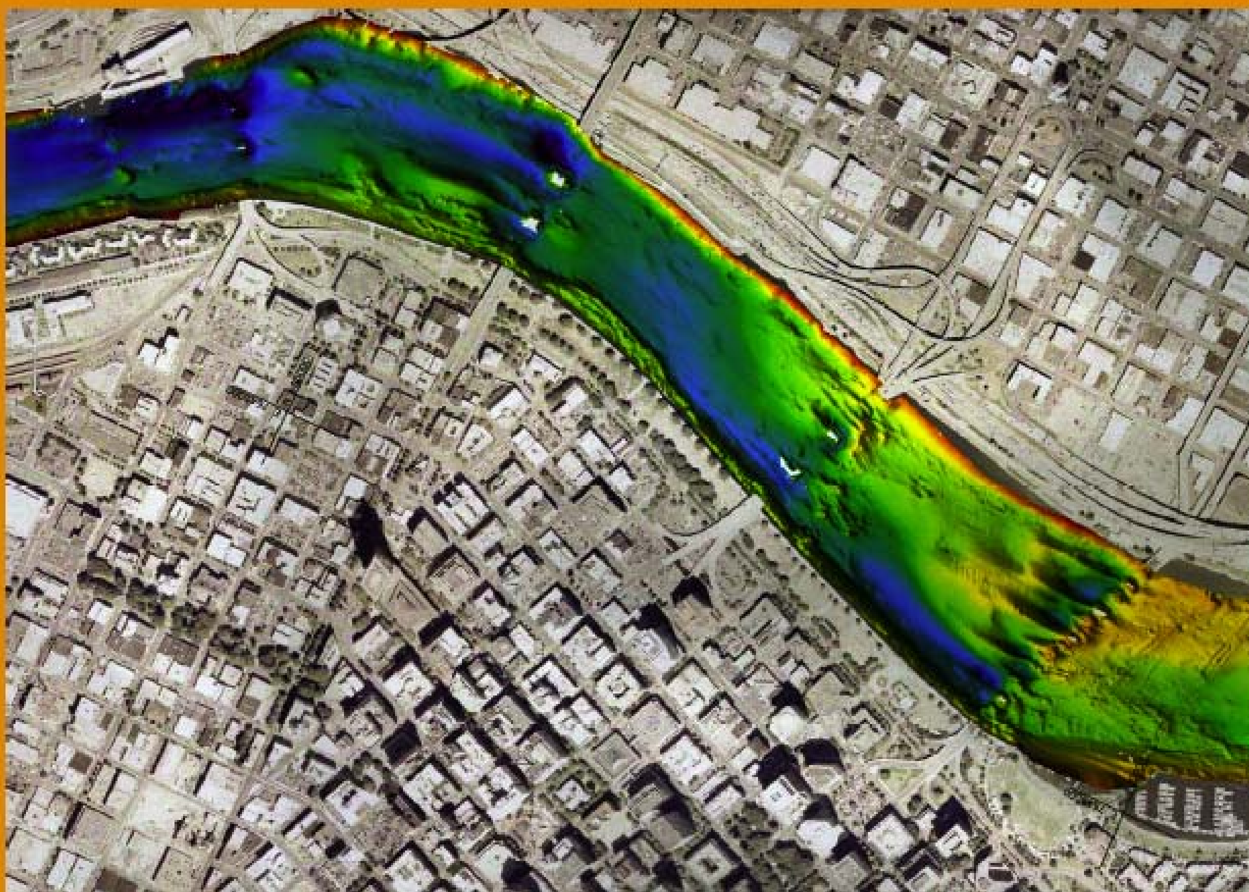
Copies: Keith Pine, Integral Consulting, Inc.
Bob Wyatt, NW Natural, LWG Co-Chair
Jim McKenna, Port of Portland, LWG Co-Chair

ATTACHMENT A

LOWER WILLAMETTE RIVER

MULTIBEAM BATHYMETRIC SURVEY REPORT

February 2004



Submitted to: Integral Consulting, Inc.

Prepared by: David Evans and Associates, Inc.
2100 SW River Parkway
Portland, OR 97201

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LOWER WILLAMETTE RIVER

MULTIBEAM BATHYMETRIC SURVEY REPORT

February 2004

Prepared by: ______________________________

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JON L. DASLER
JANUARY 23, 1990
2420

Reviewed by: ______ EXP: 12/31/05 ______

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Acronyms and Abbreviations

ASCII	American Standard Code for Information Interchange
CRD	Columbia River Datum
DEA	David Evans and Associates, Inc.
DGPS	Differential Global Positioning System
DTM	Digital Terrain Model
FGDC	Federal Geographic Data Committee
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
Hz	Hertz
kHz	Kilohertz
kCFS	One-thousand cubic feet per second
LOA	Letter of Authorization
NAD83	North American Datum of 1983
NGVD29/47	National Geodetic Vertical Datum of 1929 through the 1947 Adjustment
POS/MV	Position and Orientation System for Marine Vessels
RTK	Real-time Kinematic
SPCS	State Plane Coordinate System
WGS84	World Geodetic System of 1984

February 2004
LOWER WILLAMETTE RIVER
MULTIBEAM BATHYMETRIC SURVEY REPORT

1.0 INTRODUCTION

David Evans and Associates, Inc. (DEA), under contract with Integral Consulting, Inc. (formerly Striplin Environmental Associates), conducted a bank-to-bank multibeam bathymetric survey of the Lower Willamette River during February and March of 2004. The survey was a continuation to an ongoing sediment transport study in support of the Portland Harbor Superfund Remedial Investigation. Since the winter of 2001, periodic bank-to-bank multibeam surveys have been performed from River Mile 0 (at the confluence with the Columbia River) to River Mile 15.6 (at the upper end of Ross Island). The primary goal of the February-March survey was to create a dataset containing riverbed elevations for 2004 following a high river flow event (over 120 kCFS) that can be directly compared to prior surveys to determine areas of sediment erosion and accretion within the study area. The survey was conducted from River Mile 0 to River Mile 15.6, which is the same extent as previous surveys during the Spring of 2003, Summer of 2002 and January of 2002.

The results from this survey will be used to support sediment sampling during the Remedial Investigation; to define shoaling and scour areas relative to previous surveys; and to support future site investigations. Survey operations were conducted from February 6, 2004 to March 6, 2004 with an additional day of acquisition required on March 26th. A loose sonar power cable on February 19th resulted in the collection of data of poor quality and required a rerun of a 1-mile stretch of the river on March 26th. This report describes control used for the survey, data acquisition methodology, and data processing procedures. In addition to this report, deliverables include a set of full size drawings and project DVD-ROMs containing digital data, Arc/Info GRID files, AutoCAD drawing files and plot files of final maps.

2.0 DATUMS AND PROJECT CONTROL NETWORK

Conducting a survey on an established coordinate system, using geodetic control, enables the survey to be re-run later with repeatable results. Using a coordinate system on common horizontal and vertical datums allows for utilization of data from other sources. For this survey, the horizontal datum is the North American Datum of 1983 through the 1991 adjustment (NAD83/91), State Plane Coordinate System (SPCS), Oregon North Zone. Units are International Feet (1 foot = 0.3048 meters exactly). The vertical datum is the North American Vertical Datum of 1988 (NAVD88), which is the same vertical datum that was used in prior surveys, thereby aiding in the comparison.

Table 1: Vertical Datum Conversion

River Mile	NAVD88 Elevation	NGVD29/47 Elevation	CRD Elevation
0.4	10.0’	6.8’	5.4’
	0.0’	-3.2’	-4.6’
	-10.0’	-13.2’	-14.6’
1.3	10.0’	6.8’	5.4’
	0.0’	-3.2’	-4.7’
	-10.0’	-13.2’	-14.7’
5.0	10.0’	6.7’	4.9’
	0.0’	-3.3’	-5.1’
	-10.0’	-13.3’	-15.1’
9.8	10.0’	6.5’	4.7’
	0.0’	-3.5’	-5.3’
	-10.0’	-13.5’	-15.3’
12.8	10.0’	6.5’	4.6’
	0.0’	-3.5’	-5.4’
	-10.0’	-13.5’	-15.4’
15.6	10.0’	6.5’	4.6’
	0.0’	-3.5’	-5.4’
	-10.0’	-13.5’	-15.4’

Monument A-81, a monument used for horizontal and vertical position checks during prior surveys, was destroyed during construction activity at Terminal 4. An alternate monument T-4-28, a brass disk at the downstream corner of Berth 414, was used for checks during this survey. Position for the monument was obtained from the Port of Portland, record drawing number RG 2003-3024 titled “Rivergate Industrial District, Primary GPS Control Network, Horizontal and Vertical Control”. Elevation for monument T-4-28 was derived from a differential level run provided by the Port of Portland and conducted by Minister-Glaeser Surveying between monuments A-81 and T-4-28 (Appendix B). Table 1 is a conversion table to aid in the conversion of data based on the Columbia River Datum (CRD) or the National Geodetic Vertical Datum of 1929 through the 1947 adjustment (NGVD29/47) to NAVD88. Table 2 presents coordinates and elevations for the project control network monuments.

Table 2: Lower Willamette River, Control Network Coordinates

Monument Designation	NAD83 OR North		NAD83 OR North		NAVD88	
	North m	East m	North ft	East ft	El m	El Ft.
A81 (Destroyed)	216879.768	2322669.168	711547.800	7620305.670	9.022	29.60
T-4-28, 1999	217122.581	2322537.596	712344.427	7619874.001	9.038	29.65
BLDG10	213233.670	2325671.863	699585.530	7630157.030	10.495	34.43
DEA2828	*206352.805*	*2330026.319*	*677010.520*	*7644443.300*	*28.738*	*94.28*
2100	206776.182	2330254.088	678399.547	7645190.577	48.647	159.60
EAGLE GPS 36	211213.728	2328090.742	692958.430	7638092.990	10.146	33.29
N19	207968.621	2330368.700	682311.750	7645566.600	10.447	34.27
NELSON	202701.014	2326430.157	665029.570	7632644.870	125.250	410.93
RAINDEER	220200.425	2321017.341	722442.340	7614886.290	10.829	35.53
REF B718	211672.417	2326043.648	694463.310	7631376.800	12.600	41.34
REF N723	201209.507	2332677.212	660136.180	7653140.460	15.105	49.56
T-5-3	221705.879	2322489.162	727381.490	7619715.100	9.208	30.21
VAN CBL 0	225260.113	2325154.017	739042.370	7628458.060	9.220	30.25

3.0 BATHYMETRIC SURVEY

A high-resolution multibeam bathymetric survey was conducted to provide detailed four-dimensional data (2-D position, depth and time) over the Lower Willamette River, from River Mile 0 to River Mile 15.6. The purpose was to map changes in bathymetry after a high flow event on the Willamette relative to previous surveys in 2002 and 2003.

3.1 Survey Vessel and Crew

The vessel for this survey was the *John B. Preston*, a 30-foot custom aluminum survey boat owned and operated by DEA. The vessel is equipped with an integrated navigation and data acquisition system, and a custom mount for the SeaBat 8101 sonar head, and it is ideal for shallow water survey operations in tight quarters.

The hydrographic survey crew consisted of a lead hydrographer and vessel operator/hydrographer from DEA. The crew has conducted numerous multibeam and side-scan sonar surveys and has had extensive training in hydrographic surveys.

3.2 Positioning and Navigation

Horizontal positions were acquired with an Applanix POS/MV combined Differential Global Positioning System (DGPS) and inertial navigation system augmented by a Trimble MS 750 dual-frequency RTK receiver. The January 2002 survey strictly utilized DGPS positioning methods as the POS/MV used in the survey had difficulty maintaining RTK positions through high multipath or loss of satellite signals. Advancements in the POS/MV firmware enabled the use of RTK GPS during the Summer 2002, May 2003, and March 2004 surveys. The use of RTK GPS positioning techniques will improve horizontal positioning from +/- 1 meter to +/- 0.1 meters. RTK correctors were obtained from an RTK GPS base station deployed at three different sites to cover the survey area. They included "2100" for the upper river, "BLDG10" for the middle section, and "RAINDEER" for the lower section. Figure 1 shows the location of monuments used for RTK GPS base station deployment.

The POS/MV system integrates two GPS receivers with a motion reference unit. This system not only provides position data, but it also provides vessel heading and motion information (roll, pitch, and heave) to compute X, Y, Z data from the multibeam sonar measurements.

Position data were used in real time to provide navigation information to the vessel operator and was time-tagged and logged with multibeam and other ancillary data. The planned survey lines and the actual survey track were displayed with multibeam swath coverage in real time on a monitor located at the helm to aid in a systematic coverage of the survey area.

3.3 Water Levels Observations

Because soundings are measured relative to the water surface, accurate water level observations in the vicinity of the survey are required to account for tides and changes in river flow. Water level measurements were obtained by RTK GPS with on-the-fly ambiguity resolution. An RTK GPS base station was deployed at three separate locations to provide real-time GPS correctors. RTK correctors were applied to the shipboard GPS for logging water surface elevations at one-second intervals. An ellipsoid separation model, developed for the January 2002 survey [1] was used in Hypack MAX software for on-the-fly conversion from the WGS84 ellipsoid (ellipsoid from which GPS heights are derived) to NAVD88. One-second observations were graphically viewed and edited for outliers, artifacts from multipath, or loss of satellites. After editing of the one-second data, a 60-second moving average of RTK GPS observations was used for correcting multibeam soundings to NAVD88 elevations.

Water surface elevations obtained by RTK GPS were checked against established staff gauges installed previously by DEA at Port of Portland Terminals 2 and 5 as well as Corps of Engineers staff gauges and the Morrison Bridge staff and automated gauge.

3.4 Multibeam Data Acquisition

Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kHz. The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 feet).

Multibeam data were obtained by running lines parallel with the shoreline for the length of the project. When possible, survey lines were run to match those from prior surveys to maintain consistency between survey coverages. As with prior surveys, the sonar head was mounted with a 15-degree offset angle for horizontal orientation of the outer starboard beam. This enabled

[1] See Letter of Authorization 1

coverage over a range of 90 degrees from nadir (straight down) to starboard and 60 degrees from nadir to port with a recorded depth every 1.5 degrees. Sonar swaths were recorded at a rate of ten Hz as the vessel transited along the survey track lines. With this configuration, shoreline data were collected as far up the bank as possible by making shoreline runs with the starboard side toward shore. This allowed mapping under piers and barges with a shallow draft. Sonar beams beyond 60 degrees to port and starboard were excluded from the processed data to improve data quality. A 120-degree swath (60 degrees to port and starboard) provides bottom coverage equivalent to 3.5 times the water depth in a single pass. Therefore, the actual swath width varies with the water depth.

To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground, provided by the RTK GPS and heading data, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

Soundings were recorded simultaneously on two systems. The primary acquisition system was a Triton Elics Isis system that provided precise time tagging of the sensor data and real-time data displays for quality control. The displays include real-time side scan imagery from the multibeam sonar. The secondary acquisition system was the navigation and survey control computer running Coastal Oceanographics HYPACK MAX software. Both systems acquired and time-tagged all sensor data including multibeam sonar slant-range measurements, position, heading, heave, pitch and roll. The Coastal Oceanographics HYSWEEP program allowed the swath bathymetric data to be displayed as a painted-color-by-depth image on the navigation screen. This real-time display gave the hydrographers immediate indications of data quality and coverage.

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but also can cause refraction or bending of the path of the acoustic pulse as it passes through layers in the water column at different velocities. For this survey, a SeaBird SBE 19 SeaCat CTD profiler was used to measure conductivity, temperature, and depth at one-second intervals as the probe was lowered to just above the riverbed. The CTD measurements were used to compute an accurate velocity profile and were applied to the data during processing.

To determine the physical alignment of the multibeam transducer with the actual sonar swath and verify delay times applied to the time-tagged sensor data, a patch test was conducted. This consisted of a series of lines run in a specific pattern, which were used in pairs to analyze roll, pitch, and heading alignment angles relative to the sonar swath, as well as latency (time delays) in the time tagging of the sensor data. A patch test was conducted at the beginning of survey operations and also any time there was a change in the acquisition hardware setup such as remounting the sonar head. This ensured proper compensation for minor changes in sonar transducer mounting angles relative to the navigation sensors. Table 3 lists the date of each patch test and the corresponding transducer mounting offsets that were applied to the data through the Vessel Configuration File.

FIGURE 1: CONTROL NETWORK FOR THE LOWER WILLAMETTE RIVER

DAVID EVANS AND ASSOCIATES INC.
2100 Southwest River Parkway
Portland Oregon 97201
Phone: 503.223.6663

Table 3: February 2004 Patch Test Values

Date	Pitch	Roll	Yaw	Latency
2/6/04	-0.45º	0.03º	1.0º	0.0s
2/15/04	-0.45º	0.05º	-0.10º	0.0s
2/26/04	-0.20º	0.24º	0.0º	0.0s
3/5/05	-0.20º	0.29º	0.21º	0.0s
3/26/04	0.35º	-0.46º	0.95º	0.0s

Other quality control procedures were followed during acquisition and processing to ensure an accurate work product. A single beam crossline was run over the survey area in order to test agreement between two independent acquisition systems. The singlebeam data were logged and processed with Coastal Oceanographics HYPACK MAX software, which was used as the secondary acquisition system during the multibeam survey. Comparisons between the multibeam data set and the singlebeam soundings showed good agreement, which verified the primary acquisition and processing systems were operating properly.

4.0 DATA PROCESSING

Post-processing of multibeam data was conducted utilizing Caris HIPS multibeam analysis and presentation software. Patch test data was analyzed and alignment corrections were applied. The Caris HIPS system allows simultaneous viewing of the side scan and multibeam data to analyze anomalies on the riverbed during post-processing. Water-level data were applied to adjust all depth measurements to NAVD88 from the RTK GPS processed data. Velocity profiles were generated from CTD measurements taken in the field and used to correct slant range measurements and compensate for any ray path bending.

Processing began with review of each survey line using the Caris swath editor. Verified water level correctors were applied to the data set at this time. Position and sensor data were reviewed and accepted. Sounding data were reviewed and edited for data flyers. Sounding data, including sonar beams reflecting from sediment in the water column or noise due to aeration in the water column, were carefully reviewed before being flagged as rejected. In each case, data were not eliminated, and they can be re-accepted in the future if required.

After swath editing, all data were reviewed through the Caris HIPS subset-editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line-to-line comparison to ensure agreement to one another in a Caris session. A series of subsets was made to cover the survey area using multiple lines for each Caris session.

4.1 Data Export and Mapping

The project technical specifications call for no finer than a 10-foot grid of the data. To take advantage of the level of detail the multibeam bathymetric survey provided, a 3-foot gridded data set was exported from Caris HIPS. The gridding process used both inverse distance weighting and beam grazing angle algorithms to create the mean surfaces. These weighted surfaces were then used to create hill-shaded geo-referenced TIFF images as well as the 3-foot gridded ASCII data sets. Data were divided into sections that corresponded to final drawing sheet layouts and exported. All original data were archived at full resolution. If required at a later date, specific areas of interest can readily be remodeled at a higher resolution. It should be noted that the data are not biased for least depth as is the standard for a navigation survey and data should not be used for navigation purposes. The data processing and data generation methodology was consistent with previous surveys in order to facilitate comparison between the surveys.

For bathymetric contouring, the data comprising the 3-foot gridded dataset for each sheet was imported into Trimble Terramodel software for generation of a digital terrain model (DTM). Elevation contours were generated from the DTM at a 2-foot interval based on NAVD88. After review of the DTM, the accepted data were exported as ASCII text files corresponding to each plot sheet.

A sun-illuminated image of the multibeam data was generated in Caris HIPS at a 3-foot pixel resolution, and georeferenced TIFF files for each sheet were exported. The sun-illuminated image is color coded by depth and demonstrates the extent of bottom insonification within the survey area. Sun-illuminated images provide a more detailed presentation of the high-resolution multibeam bathymetric data than contouring and aid in the interpretation of river bedforms. The images were used as a quality control check to determine if subtle artifacts remained in the data set and subsequently incorporated into the deliverables.

4.2 GIS Processing

ArcView 3.3 was used to create the surfaces from which comparisons to earlier surveys could be conducted. ESRI grids with a 3-foot cell size were first generated from the averaged datasets exported from Caris. Difference grids were then created using the Raster Calculator function in ArcView. Grid extent, cell size and the horizontal position of the grid nodes matched those from previous surveys to ensure accuracy when the grids were compared. The values of the grid nodes for the March 2004 survey were subtracted from the grid node values for the previous surveys to produce the difference grids.

A color scale was then applied to the difference grids to aid in the analysis of the riverbed changes. The color palette was designed to accentuate the various levels of riverbed change defined by the project specifications. All areas that changed ±0.25 feet, which is the approximate vertical error budget of the survey, were colored gray. Areas of accretion (or shoaling) were given red and orange hues while those areas that eroded were given blue hues. The color values correspond to the magnitude of the difference. For example, areas shaded with dark blues signify greater change than light blues areas.

4.3 Multibeam Bathymetric Data Presentation

Results of the multibeam survey were presented as bathymetric contours and sun-illuminated imagery. Difference analysis was presented as a color-coded image. Color palettes for the sun-illuminated imagery and the difference grids matched those used on previous surveys to permit an easy visual comparison between all surveys. Table 4 is a summary of hard copy deliverables for the February 2004 survey. A detailed listing of all digital deliverables produced to date is included in Appendix A.

Table 4: Hard Copy Deliverables for February 2004 Multibeam Bathymetric Survey

	Contours **River Miles 0.0-15.6**	**Hill shaded Images** **River Miles 0.0-15.6**	**25-Month Difference Images** **January 2002 – February 2004**	**9-Month Difference Images** **May 2003 – February 2004**
Survey Date:	February 2004	February 2004	February 2004	February 2004
Delivery Date:	May 2004	May 2004	May 2004	May 2004
Sheet 1	B01	S01	DA01	DB01
Sheet 2	B02	S02	DA02	DB02
Sheet 3	B03	S03	DA03	DB03
Sheet 4	B04	S04	DA04	DB04
Sheet 5	B05	S05	DA05	DB05
Sheet 6	B06	S06	DA06	DB06
Sheet 7	B07	S07	DA07	DB07

Multibeam bathymetric contours were imported into AutoCAD and presented as a series of bathymetric contour maps (B1-B7) at a scale of 1 inch =400 ft. Aerial photographs from a 2000 aerial survey were provided by the Port of Portland to use as a base map. The aerials provided an excellent reference to the bathymetric data.

Sun-illuminated imagery of the bathymetric data was digitally overlaid on the aerial base maps and a set of sun-illuminated drawings (S1-S7) was developed in AutoCAD. The drawings included a color-by-depth legend in NAVD88 and CRD to aid in the depth determination. The colors used to define the depth are from a specific rainbow spectrum that results in images which appear to be three-dimensional when viewed with ChromaDepth glasses. The ChromaDepth glasses are available from Chromatek, Inc., at http://www.chromatek.com.

Difference images resulting from the January 2002 survey minus the February 2004 (25-month) survey are designated DA1-DA7. Difference images resulting from the May 2003 survey minus the February 2004 (9-month) survey are designated DB1-DB7. The images were imported into AutoCAD and digitally overlaid on the project base drawings. In order to accentuate areas of no data, the dark colored river on the aerial photographs was colored white. Bathymetric contours from the February 2004 survey were digitally overlaid on the difference images to aid in the interpretation of the differences.

Metadata files meeting the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata (version FGDC-STD-001-1998) were included with the digital deliverables. A detailed listing of the metadata files is included in Appendix A.

5.0 Results

Figure 2 depicts differences in surfaces created during the 25-month and 9-month difference analyses. These differences occur in a zone of large sediment waves. The February 2004 sun-illuminated imagery shows evidence of a ship grounding during a turning maneuver (bottom center of image) that was originally identified during analysis the May 2003 survey. The resulting difference can be seen in the 9- and 25-month difference analysis imagery.

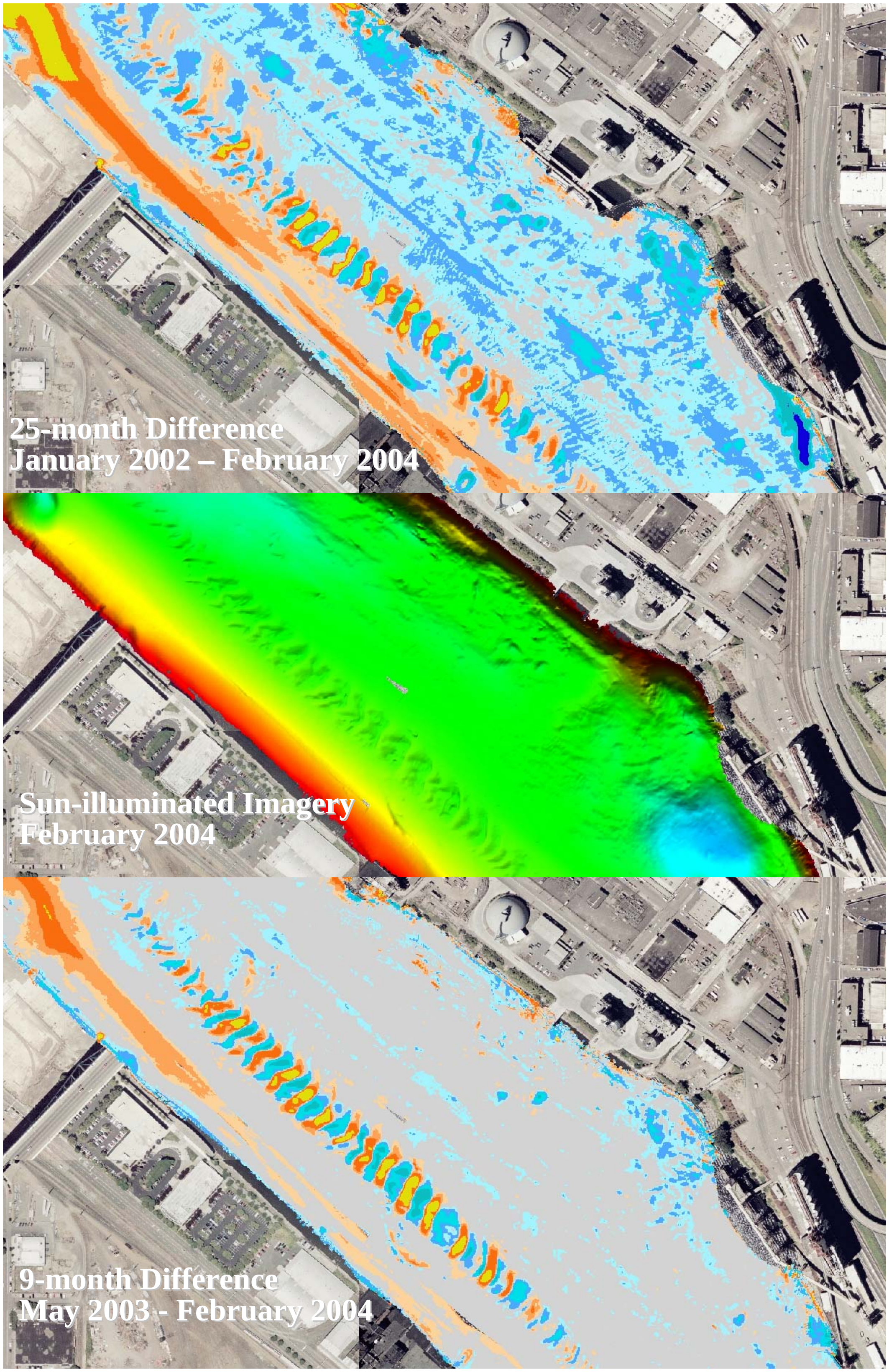


Figure 2: Comparison of Difference Analysis

As with the prior surveys, differences were detected along steep slopes that may be the result of minor vessel positioning differences between surveys. The use of RTK positioning has improved the repeatability and reliability of the surveys, but some differences that resulted from positioning still exist. Figure 3 highlights some of these areas.

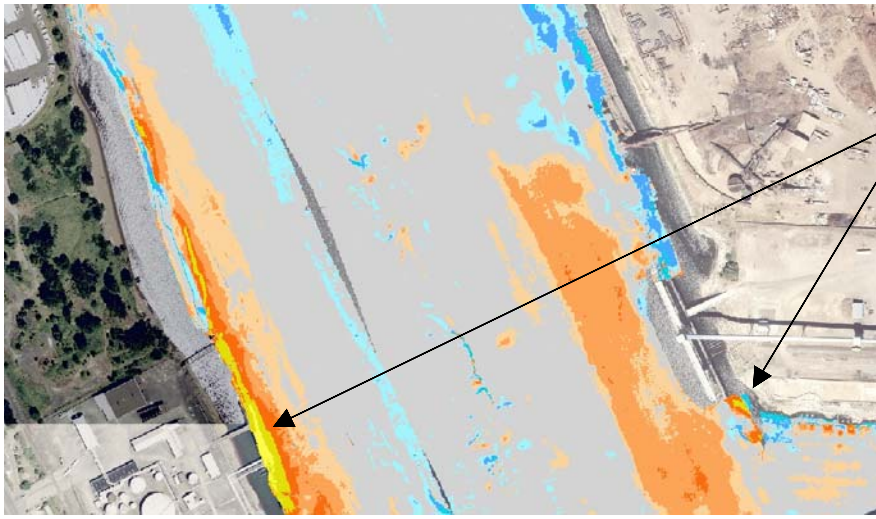


Figure 3: Differences Resulting from Marginal Positioning

Slight differences may also be observed as long linear streaks in the difference images. Some of these minor differences, those less than 0.50 feet, are the result of lower quality data originating from outer sonar beams. In general, these data are within survey tolerance. An extreme example is illustrated in Figure 4 where noisy outer beams were accepted during data processing of the January 2002 survey (LOA1).

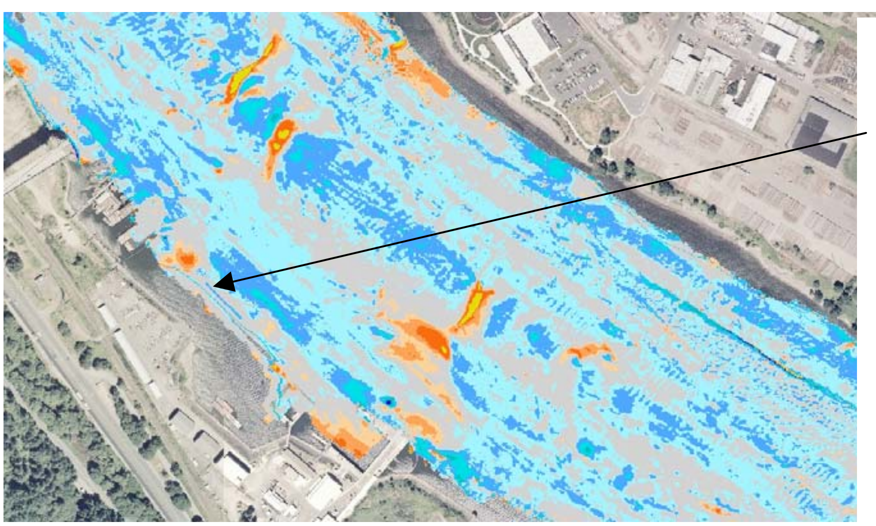
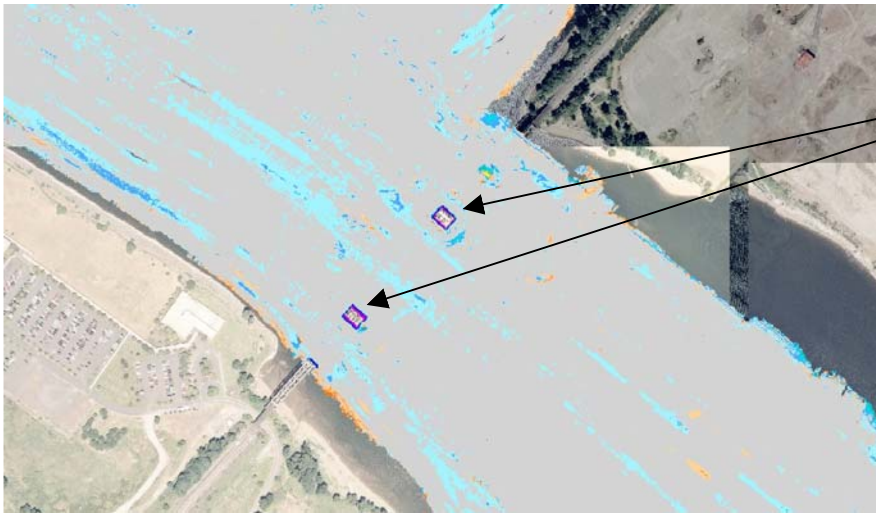


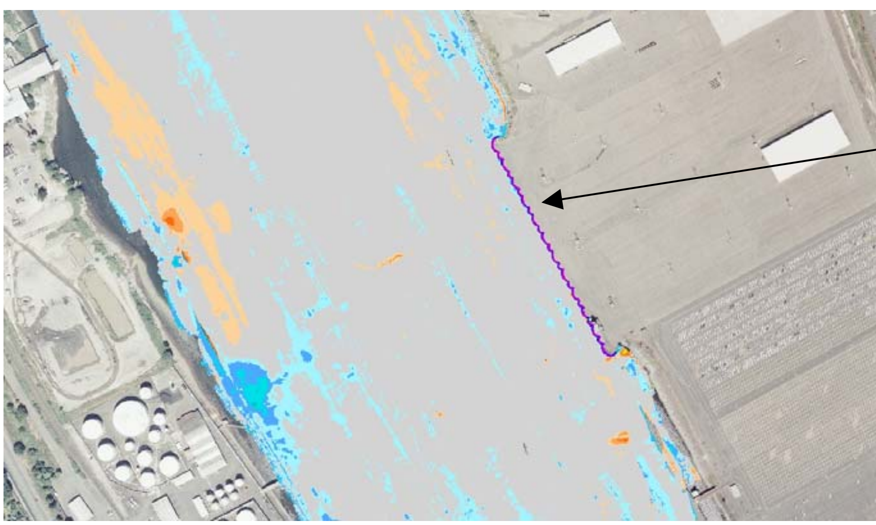
Figure 4: Differences Resulting from Noise in Outer Beams

Extreme differences are defined in the color palette by purple (greater than ten feet) and brown (greater than 30 feet). These extreme values are present at and around bridge piles throughout the survey area. Most of these areas did not change, but rather the differences in depths result from soundings collected along the vertical face of the bridge piles or pier bulkheads. Figure 5 is an example of differences that were created under this scenario.



Sheet 4 (DA4)
9-Month Difference

- Differences on bridge piles

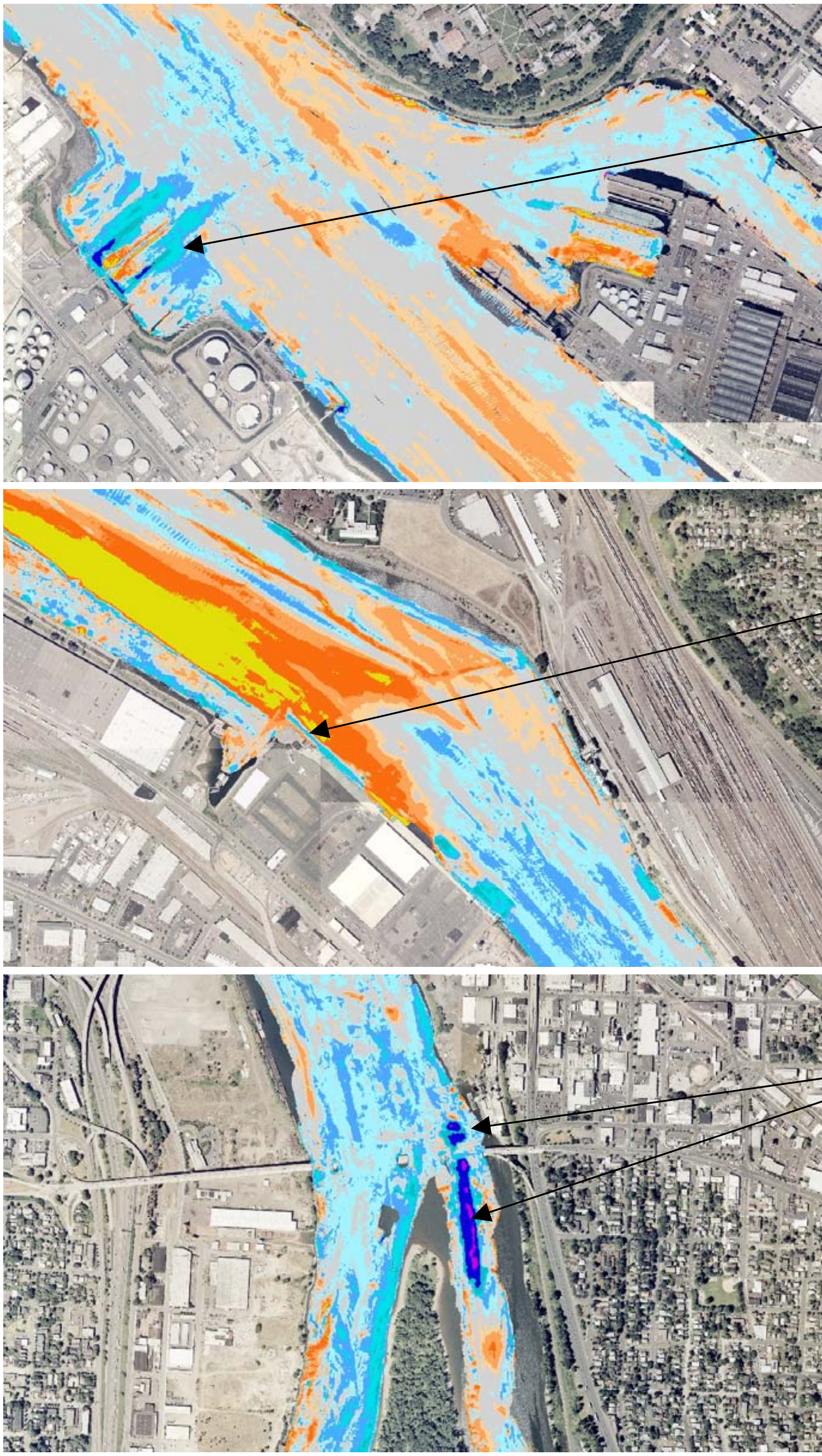


Sheet 3 (DB3)
9-Month Difference

- Differences on seawall

Figure 5: Differences Resulting from Vertical Structure

Some areas have experienced change resulting from dredging operations. Figure 6 identifies some of these areas together with the magnitude of the change.



Sheet 4 (DA4)
25-Month Difference
- Differences resulting from dredging

Sheet 5 (DA5)
25-Month Difference
- Differences resulting from dredging shown in blue

Sheet 7 (DA7)
25-Month Difference
- Differences resulting from dredging

Figure 6: Differences Resulting from Dredging

By enlarge, the minor differences from positioning, outer beam noise, dredging activity and vertical structures mentioned above are benign in nature and cover a relatively small portion of the data set. The resultant datasets generated over a 25-month period present a detailed depiction of sediment transport through the Portland Harbor at a high resolution. Bedforms such as pockets from historic dredge activity are being infilled on the upstream side and scoured on the downstream side (Figure 7).

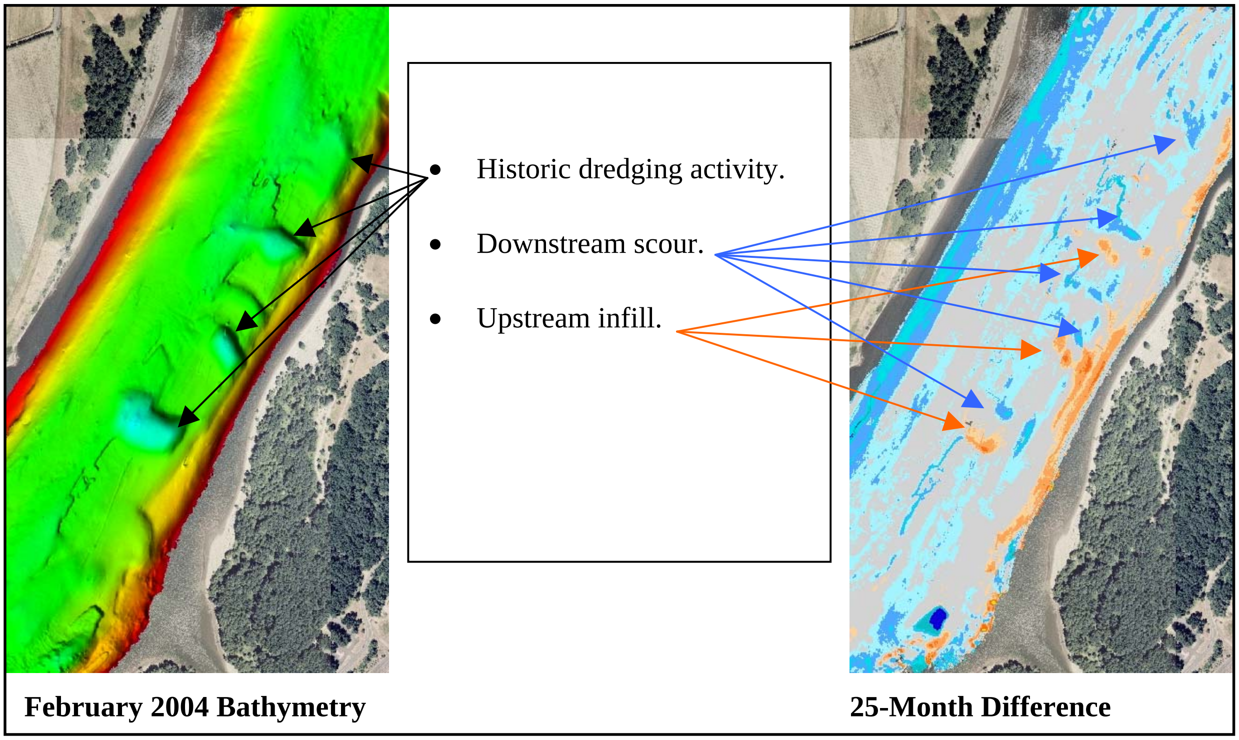


Figure 7: Sediment transport over a 25-month period at historic dredge sites.

Large areas of infill were identified on the inside of bends in the river and other areas where deflections in river currents have created shoals and other bedforms. The shoal downstream of Terminal 2 has infilled up to 3-feet and large sediment bedforms have continued to accumulated sediment near the site of old Terminal 1 (Figure 8). Detailed evaluation of the datasets generated by the 25-month bathymetric study continue to reveal the complexity of the sediment transport mechanisms at work in the Portland Harbor and are a valuable component to the overall Remedial Investigation.

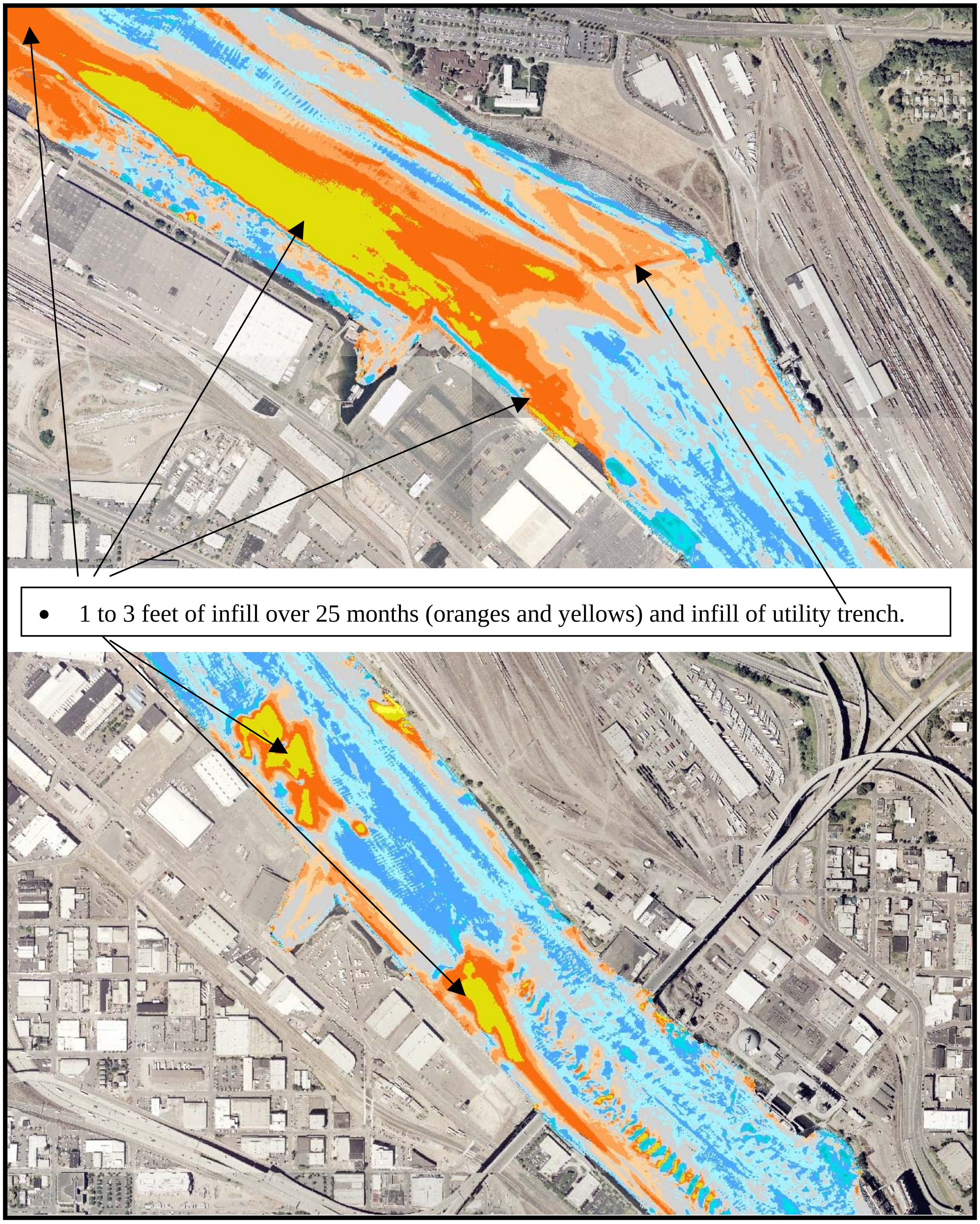


Figure 8: Sediment infill over a 25-month period near Terminal 2 and site of old Terminal 1.

APPENDIX A
FEBRUARY 2004 DIGITAL DATA CATALOG

May 2004 Digital Data Catalog

	LOA1 (January 2002)				
	AutoCAD files			AutoCAD plot files	
	Bathymetry	Sun-illuminated	Contours	Bathymetry	Sun-illuminated
Sheet 1	bathy_01.dwg	sunil_01.dwg	sh1_con.dwg	bathy_01.plt	sunil_01.plt
Sheet 2	bathy_02.dwg	sunil_02.dwg	sh2_con.dwg	bathy_02.plt	sunil_02.plt
Sheet 3	bathy_03.dwg	sunil_03.dwg	sh3_con.dwg	bathy_03.plt	sunil_03.plt
Sheet 4	bathy_04.dwg	sunil_04.dwg	sh4_con.dwg	bathy_04.plt	sunil_04.plt
Sheet 5	bathy_05.dwg	sunil_05.dwg	sh5_con.dwg	bathy_05.plt	sunil_05.plt
Sheet 6	bathy_06.dwg	sunil_06.dwg	sh6_con.dwg	bathy_06.plt	sunil_06.plt
Sheet 7	bathy_07.dwg	sunil_07.dwg	sh7_con.dwg	bathy_07.plt	sunil_07.plt
	Imagery with worldfile				
	Sun-illuminated bathymetry images				
Sheet 1	sheet1_1m_ev50_az45.tif				
Sheet 2	sheet2_1m_ev55_az20.tif				
Sheet 3	sheet3_1m_ev55_az350.tif				
Sheet 4	sheet4_1m_b_ev55_az350.tif				
Sheet 5	sheet5_1m_ev55_az350.tif				
Sheet 6	sheet6_1m_ev55_az340.tif				
Sheet 7	sheet7_1m_ev55_az45.tif				
	ArcGRID				
	1m Bathymetry	10ft Bathymetry	10ft Bathymetry and Lidar		
Sheet 1	sh1_loa4_1m.e00	sht1_bath10ft.e00	sht1_bath_lid.e00		
Sheet 2	sht2_loa3_1m.e00	sht2_bath10ft.e00	sht2_bath_lid.e00		
Sheet 3	sht3_loa3_1m.e00	sht3_bath10ft.e00	sht3_bath_lid.e00		
Sheet 4	sht4_loa3_1m.e00	sht4_bath10ft.e00	sht4_bath_lid.e00		
Sheet 5	sht5_loa3_1m.e00	sht5_bath10ft.e00	sht5_bath_lid.e00		
Sheet 6	sht6_loa4_1m.e00	sht6_bath10ft.e00	sht6_bath_lid.e00		
Sheet 7	sht7_loa4_1m.e00	sht7_bath10ft.e00	sht7_bath_lid.e00		
	ASCII Points				
	1m XYZ	1m XYZ	10ft XYZ		
Sheet 1	sht1_bathy_1m_xyz.txt	na	sht1_bath10ft_xyz.txt		
Sheet 2	sht2_bathy_1m_xyz.txt	na	sht2_bath10ft_xyz.txt		
Sheet 3	sht3_bathy_1m_xyz.txt	na	sht3_bath10ft_xyz.txt		
Sheet 4	sht4_bathy_1m_xyz_east.txt	sht4_bathy_1m_xyz_west.txt	sht4_bath10ft_xyz.txt		
Sheet 5	sht5_bathy_1m_xyz_east.txt	sht5_bathy_1m_xyz_west.txt	sht5_bath10ft_xyz.txt		
Sheet 6	sht6_bathy_1m_xyz.txt	na	sht6_bath10ft_xyz.txt		
Sheet 7	sht7_bathy_1m_xyz.txt	na	sht7_bath10ft_xyz.txt		
	Other files				
	bathym_10ft.e00	10 ft bathymetry mosaic			
	bathlid_merge.e00	bathymetry and lidar mosaic			
	Loa1_tracks.dxf	survey tracklines			

May 2004 Digital Data Catalog

	LOA3 (July 2002)				
	AutoCAD files				
	Bathymetry	Sun-illuminated	Difference	2ft Contours	5ft Contours
Sheet 1	na	na	na	na	na
Sheet 2	bathy_02.dwg	sunil_02.dwg	diff_02.dwg	sh2_con.dwg	sh2_5ft.dwg
Sheet 3	bathy_03.dwg	sunil_03.dwg	diff_03.dwg	sh3_con.dwg	sh3_5ft.dwg
Sheet 4	bathy_04.dwg	sunil_04.dwg	diff_04.dwg	sh4_con.dwg	sh4_5ft.dwg
Sheet 5	bathy_05.dwg	sunil_05.dwg	diff_05.dwg	sh5_con.dwg	sh5_5ft.dwg
Sheet 6	na	na	na	na	na
Sheet 7	na	na	na	na	na
	Imagery with worldfile				
	Sun-illuminated bathymetry images	Bathymetry difference 3v1			
Sheet 1	na	na			
Sheet 2	sheet2_1m-24_v5.tif	diff_2			
Sheet 3	sheet3_1m.tif	diff_3			
Sheet 4	sheet4_1m.tif	diff_4			
Sheet 5	sheet5_1m.tif	diff_5-new			
Sheet 6	na	na			
Sheet 7	na	na			
	ArcGRID				
	1m Bathymetry	Bathymetry difference 3v1			
Sheet 1	na	na			
Sheet 2	sh2_loa3_1m.e00	diff_2.e00			
Sheet 3	sh3_loa3_1m.e00	diff_3.e00			
Sheet 4	sh4_loa3_1m.e00	diff_4.e00			
Sheet 5	sh5_loa3_1m.e00	diff_5b.e00			
Sheet 6	na	na			
Sheet 7	na	na			
	ASCII Points				
	1m XYZ				
Sheet 1	na				
Sheet 2	sh2_loa3_1m_xyz.txt				
Sheet 3	sh3_loa3_1m_xyz.txt				
Sheet 4	sh4_loa3_1m_xyz.txt				
Sheet 5	sh5_loa3_1m_xyz.txt				
Sheet 6	na				
Sheet 7	na				
	Other files				
	Loa3_tracks.dxf	survey tracklines			

May 2004 Digital Data Catalog

	LOA4 (September 2002)					
	AutoCAD files					
	Bathymetry	Sun-illuminated	Difference	2ft Contours	2ft Contours	Contour labels
Sheet 1	bathy_01.dwg	sunil_01.dwg	diff_01.dwg	sh1_con.dwg	sh1_5ft.dwg	sh1_labels.dwg
Sheet 2	bathy_02.dwg	sunil_02.dwg	diff_02.dwg	sh2_con.dwg	sh2_5ft.dwg	sh2_labels.dwg
Sheet 3	na	na	na	na	na	na
Sheet 4	na	na	na	na	na	na
Sheet 5	bathy_05.dwg	sunil_05.dwg	diff_05.dwg	sh5_con.dwg	sh5_5ft.dwg	sh5_labels.dwg
Sheet 6	bathy_06.dwg	sunil_06.dwg	diff_06.dwg	sh6_con.dwg	sh6_5ft.dwg	sh6_labels.dwg
Sheet 7	bathy_07.dwg	sunil_07.dwg	diff_07.dwg	sh7_con.dwg	sh7_5ft.dwg	sh7_labels.dwg
	Imagery with worldfile					
	Sun-illuminated bathymetry images	Bathymetry difference 4v1	Bathymetry difference 4v3			
Sheet 1	sheet1_loa4.tif	diff1_4v1.tif	na			
Sheet 2	sheet2_loa4.tif	diff2_4v1.tif	diff2_4v3.tif			
Sheet 3	na	na	na			
Sheet 4	na	na	na			
Sheet 5	sheet5_loa4.tif	diff5_4v1.tif	diff5_4v3.tif			
Sheet 6	sheet6_loa4.tif	diff6_4v1.tif	na			
Sheet 7	sheet7_loa4.tif	diff7_4v1.tif	na			
	ArcGRID					
	1m Bathymetry	Bathymetry difference 4v1	Bathymetry difference 4v3			
Sheet 1	sh1_loa4_1m.e00	diff1_4v1.e00	na			
Sheet 2	sh2_loa4.e00	diff2_4v1.e00	diff2_4v3.e00			
Sheet 3	na	na	na			
Sheet 4	na	na	na			
Sheet 5	sh5_loa4.e00	diff5_4v1.e00	diff5_4v3.e00			
Sheet 6	sht6_loa4.e00	diff6_4v1.e00	na			
Sheet 7	sh7_loa4.e00	diff7_4v1.e00	na			
					LOA1 UPDATE	
	ASCII Points				ArcGRID	
	1m XYZ				1m Bathymetry	
Sheet 1	sh1_loa4_1m_xyz.txt				na	
Sheet 2	sh2_loa4_1m_xyz.txt				na	
Sheet 3	na				na	
Sheet 4	na				na	
Sheet 5	sh5_loa4_1m_xyz.txt				na	
Sheet 6	sh6_loa4_1m_xyz.txt				sh6_loa1_msk.e00	
Sheet 7	sh7_loa4_1m_xyz.txt				sh7_loa1_msk.e00	
	Other files					
	Loa4_tracks.dxf	survey tracklines				

May 2004 Digital Data Catalog

	LOA6 (May 2003)			
	AutoCAD files			
	Bathymetry	Sun-illuminated	16-month Difference	10-month Difference
Sheet 1	bathy_01.dwg	sunil_01.dwg	diffa_01.dwg	diffb_01.dwg
Sheet 2	bathy_02.dwg	sunil_02.dwg	diffa_02.dwg	diffb_02.dwg
Sheet 3	bathy_03.dwg	sunil_03.dwg	diffa_03.dwg	diffb_03.dwg
Sheet 4	bathy_04.dwg	sunil_04.dwg	diffa_04.dwg	diffb_04.dwg
Sheet 5	bathy_05.dwg	sunil_05.dwg	diffa_05.dwg	diffb_05.dwg
Sheet 6	bathy_06.dwg	sunil_06.dwg	diffa_06.dwg	diffb_06.dwg
Sheet 7	bathy_07.dwg	sunil_07.dwg	diffa_07.dwg	diffb_07.dwg
	Imagery with worldfile			
	Sun-illuminated bathymetry images	16-month difference (Loa6v1)	10-month difference (Loa6v3)	10-month difference (Loa6v4)
Sheet 1	sheet1_loa6.tif	diff1_6v1.tif	na	diff1_6v4.tif
Sheet 2	sheet2_loa6.tif	diff2_6v1.tif	diff2_6v3.tif	na
Sheet 3	sheet3_loa6.tif	diff3_6v1.tif	diff3_6v3.tif	na
Sheet 4	sheet4_loa6.tif	diff4_6v1.tif	diff4_6v3.tif	na
Sheet 5	sheet5_loa6.tif	diff5_6v1.tif	diff5_6v3.tif	na
Sheet 6	sheet6_loa6.tif	diff6_6v1.tif	na	diff6_6v4.tif
Sheet 7	sheet7_loa6.tif	diff7_6v1.tif	na	diff7_6v4.tif
	ArcGRID			
	1m Bathymetry	16-month difference (Loa6v1)	10-month difference (Loa6v3)	10-month difference (Loa6v4)
Sheet 1	sht1_loa6_1m.e00	diff1_6v1.e00	na	diff1_6v4.e00
Sheet 2	sht2_loa6_1m.e00	diff2_6v1.e00	diff2_6v3.e00	na
Sheet 3	sht3_loa6_1m.e00	diff3_6v1.e00	diff3_6v3.e00	na
Sheet 4	sht4_loa6_1m.e00	diff3_6v1.e00	diff4_6v3.e00	na
Sheet 5	sht5_loa6_1m.e00	diff5_6v1.e00	diff5_6v3.e00	na
Sheet 6	sht6_loa6_1m.e00	diff6_6v1.e00	na	diff6_6v4.e00
Sheet 7	sht7_loa6_1m.e00	diff7_6v1.e00	na	diff7_6v4.e00
	ASCII Points			
	1m XYZ			
Sheet 1	sh1_loa6_1m_xyz.txt			
Sheet 2	sh2_loa6_1m_xyz.txt			
Sheet 3	sh3_loa6_1m_xyz.txt			
Sheet 4	sh4_loa6_1m_xyz.txt			
Sheet 5	sh5_loa6_1m_xyz.txt			
Sheet 6	sh6_loa6_1m_xyz.txt			
Sheet 7	sh7_loa6_1m_xyz.txt			
	AutoCAD Plot Files			
	Bathymetry	Sun-illuminated	16-month Difference	10-month Difference
Sheet 1	bathy_01.plt	sunil_01.plt	diffa_01.plt	diffb_01.plt
Sheet 2	bathy_02.plt	sunil_02.plt	diffa_02.plt	diffb_02.plt
Sheet 3	bathy_03.plt	sunil_03.plt	diffa_03.plt	diffb_03.plt
Sheet 4	bathy_04.plt	sunil_04.plt	diffa_04.plt	diffb_04.plt
Sheet 5	bathy_05.plt	sunil_05.plt	diffa_05.plt	diffb_05.plt
Sheet 6	bathy_06.plt	sunil_06.plt	diffa_06.plt	diffb_06.plt
Sheet 7	bathy_07.plt	sunil_07.plt	diffa_07.plt	diffb_07.plt
	Other data			
	Loa6_tracks.dxf	survey tracklines		
		10ft XYZ		
	Merged Data	bathy_LOA6_10ft_xyz.txt		
	Merged Data	diff_loa6v1_LOA6_10ft_xyz.txt		
	Merged Data	diff_loa6v3-4_LOA6_10ft_xyz.txt		

May 2004 Digital Data Catalog

	LOA7 (March 2004)			
	AutoCAD files			
	Bathymetry	Sun-illuminated	25-month Difference	9-month Difference
Sheet 1	bathy_01.dwg	sunil_01.dwg	diffa_01.dwg	diffb_01.dwg
Sheet 2	bathy_02.dwg	sunil_02.dwg	diffa_02.dwg	diffb_02.dwg
Sheet 3	bathy_03.dwg	sunil_03.dwg	diffa_03.dwg	diffb_03.dwg
Sheet 4	bathy_04.dwg	sunil_04.dwg	diffa_04.dwg	diffb_04.dwg
Sheet 5	bathy_05.dwg	sunil_05.dwg	diffa_05.dwg	diffb_05.dwg
Sheet 6	bathy_06.dwg	sunil_06.dwg	diffa_06.dwg	diffb_06.dwg
Sheet 7	bathy_07.dwg	sunil_07.dwg	diffa_07.dwg	diffb_07.dwg
	Imagery with worldfile			
	Sun-illuminated bathymetry images	25-month difference (Loa7v1)	9-month difference (Loa7v6)	
Sheet 1	sheet1_loa7.tif	diff1_7v1.tif	diff1_7v6.tif	
Sheet 2	sheet2_loa7.tif	diff2_7v1.tif	diff2_7v6.tif	
Sheet 3	sheet3_loa7.tif	diff3_7v1.tif	diff3_7v6.tif	
Sheet 4	sheet4_loa7.tif	diff4_7v1.tif	diff4_7v6.tif	
Sheet 5	sheet5_loa7.tif	diff5_7v1.tif	diff5_7v6.tif	
Sheet 6	sheet6_loa7.tif	diff6_7v1.tif	diff6_7v6.tif	
Sheet 7	sheet7_loa7.tif	diff7_7v1.tif	diff7_7v6.tif	
	ArcGRID			
	1m Bathymetry	25-month difference (Loa7v1)	9-month difference (Loa7v6)	
Sheet 1	sht1_loa7_1m.e00	diff1_7v1.e00	diff1_7v6.e00	
Sheet 2	sht2_loa7_1m.e00	diff2_7v1.e00	diff2_7v6.e00	
Sheet 3	sht3_loa7_1m.e00	diff3_7v1.e00	diff3_7v6.e00	
Sheet 4	sht4_loa7_1m.e00	diff4_7v1.e00	diff4_7v6.e00	
Sheet 5	sht5_loa7_1m.e00	diff5_7v1.e00	diff5_7v6.e00	
Sheet 6	sht6_loa7_1m.e00	diff6_7v1.e00	diff6_7v6.e00	
Sheet 7	sht7_loa7_1m.e00	diff7_7v1.e00	diff7_7v6.e00	
	ASCII Points			
	1m XYZ			
Sheet 1	sh1_loa7_1m_xyz.txt			
Sheet 2	sh2_loa7_1m_xyz.txt			
Sheet 3	sh3_loa7_1m_xyz.txt			
Sheet 4	sh4_loa7_1m_xyz.txt			
Sheet 5	sh5_loa7_1m_xyz.txt			
Sheet 6	sh6_loa7_1m_xyz.txt			
Sheet 7	sh7_loa7_1m_xyz.txt			
	AutoCAD Plot Files			
	Bathymetry	Sun-illuminated	25-month Difference	9-month Difference
Sheet 1	bathy_01.plt	sunil_01.plt	diffa_01.plt	diffb_01.plt
Sheet 2	bathy_02.plt	sunil_02.plt	diffa_02.plt	diffb_02.plt
Sheet 3	bathy_03.plt	sunil_03.plt	diffa_03.plt	diffb_03.plt
Sheet 4	bathy_04.plt	sunil_04.plt	diffa_04.plt	diffb_04.plt
Sheet 5	bathy_05.plt	sunil_05.plt	diffa_05.plt	diffb_05.plt
Sheet 6	bathy_06.plt	sunil_06.plt	diffa_06.plt	diffb_06.plt
Sheet 7	bathy_07.plt	sunil_07.plt	diffa_07.plt	diffb_07.plt
	Other data			
	survey tracklines	Loa7_tracks.dwg		
		10ft XYZ		
	Merged Data	bathy_LOA7_10ft_xyz.txt		
	Merged Data	diff_loa7v1_LOA7_10ft_xyz.txt		
	Merged Data	diff_loa7v6_LOA7_10ft_xyz.txt		

	Metadata			
	Data Type	Metadata File		
	Imagery with worldfile			
	Sun-illuminated bathymetry images	Sheet*_loa7.htm		
	25-month difference (Loa7v1)	Diff*_7v1.htm		
	9-month difference (Loa7v6)	Diff*_7v6.htm		
	ArcGRID			
	1m Bathymetry	Sht*_loa7_1m.htm		
	25-month difference (Loa7v1)	Diff*_7v1.htm		
	9-month difference(Loa7v6)	Diff*_7v6.htm		
	ASCII Points			
	1m Bathymetry XYZ	Sh*_loa7_1m_xyz.htm		
	10ft XYZ			
	Bathymetry	bathy_LOA7_10ft_xyz.txt		
	25-month difference (Loa7v1)	diff_loa7v1_LOA7_10ft.htm		
	9-month difference (Loa7v6)	diff_loa7v6_LOA7_10ft.htm		
	* denotes sheet number (1-7)			

APPENDIX B
DIFFERENTIAL LEVEL NOTES AT TERMINAL 4

K. JOHNSON
N. GIBSON
6/24/03

BY MINISTER-GLASER

PORT OF PORTLAND
LEVELS
03-203

TERMINAL 4

B415 / B414

= BRASS DISC, IN CONC. (E) END OF DOCK

= BRASS DISC IN BOX, ACROSS RD (W) OF TOYOTA PARKING

STA	BS	HI	FS	ELEV
A81				26.267 ✓ per T4 2000-3024
	4.247	30.514		
TP-1			4.045	26.469
	3.726	30.195		
TP-2			4.276	25.919
	4.976	30.895		
TP-3			0.824	30.071
	8.436	38.507		
TP-4			4.763	33.744
	4.104	37.848		
TP-5			3.139	34.709
	3.618	38.327		
TP-6			4.417	33.910
	5.200	39.110		
#4-B			3.819	35.291
	3.568	38.859		
TP-7			5.660	33.199
	6.562	39.761		
TP-8			6.007	33.754
	5.037	38.791		
TP-9			5.333	33.458
	4.640	38.098		
TP-10			10.311	27.787

T-4-28 = BRASS DISC DOWNSTREAM CORNER OF B414

A81 = BRASS DISC IN UPSTREAM CORNER OF B415

STA	BS	HI	FS	ELEV	
				27.787	
~~TBM1~~	2.542	30.329			
T-4-28			4.012	26.317	9.038m NAVD88
	3.989	30.306			
TP-11			4.638	25.668	Δ= +0.054 FT Δ= +0.016 m
	4.821	30.489			
TP-12			4.376	26.113	
	4.701	30.814			
A-81			4.551	26.263	9.022 m NAVD 88
				(26.267)	
			EOC =	.004	

CALC. BY DAVID EVANS AND ASSOCIATES